ANSWERS: Relate concentration to pH and conductivity

1) The pH of a solution depends on the concentration of H_3O+ ions in solution. HCl is a strong acid, so it fully dissociates in water to form H_3O+ ions and Cl^- ions.

$HCl + H_2O \rightarrow H_3O+ Cl^-$

Therefore $[H_3O^+] = [HCl]$ so the pH is very low (1.0)

Similarly, NaOH is a strong base which fully dissociates in water

$(NaOH \xrightarrow{H_2O} Na^+ + OH^-$

so $[OH^-] > [H_3O^+]$ and it has a high pH of 13.0

NH_4Cl firstly separates into NH_4^+ and Cl^- ions when it dissolves and NH_4^+ is a weak base which partially dissociates in water.

$NH_4^+ + H_2O \rightleftarrows H_3O^+ + NH_3$

Therefore as the $[H_3O^+]$ is increased the pH is below 7, but only very little NH_4^+ dissociates so the pH is higher than that of HCl. NH_3 is a weak base which also partially dissociates in water

$NH_3 + H_2O \rightleftarrows OH^- + NH_4^+$

So the concentration of OH^- ions in solution is increased so the pH is above 7 but as NH_3 only partially dissociates the pH is lower than that of NaOH.

The conductivity of a solution depends on the concentration of charged particles (ions) in solution which can carry the flow of charge. HCl, NH_4Cl and NaOH all completely separate into cations and anions when they are dissolved in water, so the solutions have a high concentration of ions which carry a current so that all have high conductivity. In a solution of NH_3, however, the only ions present are those formed from the dissociation of the base into OH^- and NH_4^+ ions and as NH_3 is a weak base only very little dissociates. Therefore the concentration of ions in aqueous solution is lower so it has low conductivity.

$NH_4^+ + H_2O \rightleftarrows OH^- + NH_4^+$

2)

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

Equilibrium is to the left, so the greatest concentration of a species is NH_3. For each NH_3 that reacts equal amounts of NH_4^+ and OH^- are formed and are greater than the OH^- and H_3O^+ formed by the dissociation of water.

$NH_3 > OH^- \geq NH_4^+ > H_3O^+$

$HF + H_2O \rightleftharpoons F^- + H_3O^+$

Equilibrium is to the left, so the greatest concentration of a species is HF. For each HF that reacts equal amounts of F^- and H_3O^+ are formed and are greater than the OH^- and H_3O^+ formed by the dissociation of water.

$HF > H_3O^+ \geq F^- > OH^-$

3) pK_a of methanoic acid is smaller so it is a stronger acid (more acid is dissociated) and therefore higher $[H_3O^+]$. High $[H_3O^+]$ = low pH

4) CH_3NH_2 is a weak base and only reacts slightly with water / it is a weak base, equilibrium lies to the left/only partial dissociation.

As most aminomethane remains in the molecular state there are few ions in the solution, making it a weak electrolyte.

5) $NH_3(aq) + H_2O \leftrightarrow NH_4^+(aq) + OH^-(aq)$

As NH_4Cl dissolves $[NH_4^+]$ is increased. This causes the equilibrium to move to favour formation of reactants so that $[OH^-]$ is decreased. As $[OH^-]$ is decreased, $[H_3O^+]$ is increased and pH is decreased.

6) HCl, NH_4Cl, NaCl, NH_3, NaOH

HCl – strong acid, fully dissociates giving high concentration of H_3O^+.
$HCl + H_2O \rightarrow H_3O^+ + Cl^-$

NH4Cl dissolves to give a solution of
NH_4^+ and Cl^- ions. The NH_4^+ ions are weakly acidic and partially dissociate in water to give a small increase in $[H_3O^+]$.
$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$

NaCl dissolves to give Na^+ and Cl^- ions, but neither of these have any reaction with water so solution is neutral.

NH_3 is a weak base and reacts with water to give a small increase in the conc of OH^-, making the solution weakly alkaline.
$NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-$

NaOH is a strong base and fully dissociates, giving a high concentration of OH^- ions.
$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

7) Statement is incorrect – it should be that 8 mol L^{-1} acid is more concentrated than 0.02 mol L^{-1} .
or
one acid is stronger than another if it dissociates into ions (H_3O^+ and A^-) more readily.
or
similar correct statement.

8) K_a for CCl_3COOH ($10^{-0.70}$) is > K_a for CH_3COOH ($10^{-4.75}$)
So the numerator of the K_a expression is larger and $[H_3O^+]$ is therefore higher so the CCl_3COOH is the stronger of the two acids.